A longitudinal perspective of climate adaptation

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A longitudinal perspective of climate adaptation; a case study from the water sector 2013-2023

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Yorkshire Water provides clean water and wastewater treatment for over five million customers in the north of England, UK. Weather and climate determine water supply, and extreme weather, particularly flooding, can severely alter their operations and ability to process wastewater. This article provides a unique longitudinal (2013-2023) perspective of how an infrastructure owner and operator has responded to changing policy contexts and embedded climate adaptation within operational processes. The uptake in adaptation measures was driven by a combination of factors including the Adaptation Reporting Power mandated by the Climate Change Act, increased availability of climate data, the need to recover from extreme weather events, particularly flooding, and changes to water management policies. The latter have instigated greater partnership working to reduce risk associated with flood events, and placed more emphasis on managing water via landscape-led natural processes such as Natural Flood Management, with actions delivered through partnership working. This article describes Yorkshire Water's leadership in the early days of adaptation within the UK and discusses the changing policy frameworks, business needs, climate knowledge, and societal context that have led to more holistic and sustainable water resource management.

Key words: infrastructure resilience, Adaptation Reporting Power, Nature based Solutions, flood risk management,

1. Introduction

Yorkshire Water is responsible for providing clean water and treating wastewater for over five million people and businesses across the north of England (Figure 1). Their service region includes the large cities of Leeds, Sheffield, Bradford, and Hull, and three National Parks. The region is climatically diverse with the eastern part of the region receiving approximately 40% less rainfall than the west (Wheeler, 2013). The western and southern uplands are home to internationally important peatbog habitats (Armstrong et al., 2010) and are the source of around 40% of the region's raw water. In the centre of the region, drinking water is drawn from the large rivers; in the southern and eastern parts of the region, including the Yorkshire Wolds, water is largely sourced from underground aquifers, drawn up through boreholes.

There are 53 water treatment works serving the population of Yorkshire. Water is treated and delivered to homes via a pressurized, sealed network. Drinking water is generally less than two hours old from treatment to tap and interruptions to supply are rare. Quality is governed by EU drinking water standards and tested and assured by the Drinking Water Inspectorate. Yorkshire Water estimate that approximately 20% of water of treated water is lost to leaks, of which only 6% are visible. Yorkshire Water are also responsible for the collection, treatment, and safe disposal of sewage. Across most of the region, sewage from homes is combined with rainwater from roofs, gardens and roads and is conveyed by gravity to one of around 600 wastewater treatment works. In rural areas these are very small works using passive biological treatment processes. In urban areas, sewage treatment works are large industrial sites treating thousands of litres of sewage per minute and have more sophisticated treatment processes. These works also act as central hubs for tertiary processing of sewage sludge, digesting and processing sludge from across the region's wastewater treatment works, to extract energy and ensuring the end product is safe for use on land.

Understanding weather and changing climate is paramount for Yorkshire Water. Weather and climate determine the availability of their key product, and extreme weather, particularly flooding, can severely alter their operations and ability to process wastewater. Over the last 15 years, the policies governing water management have changed rapidly (Figure 2). This article describes how Yorkshire Water responded to this changing policy context in order to embed climate adaptation within their operations and switch to more holistic and sustainable water resource management. Conceptually, this article provides a unique longitudinal perspective on the challenges and advances of climate adaptation for an infrastructure owner and operator. It contributes to our knowledge of climate adaptation and takes forward existing work that has considered the utility of adaption reporting (Jude et al., 2017; Street and Jude, 2019) and identified infrastructure adaptation actions (Jenkins et al., 2022). This detailed exploration of iterative climate adaptation will be useful for other infrastructure owners, particularly those who are earlier on their climate change adaptation journey. Practically, this case study of climate adaptation feeds into the next UK Climate Change Risk Assessment, the National Adaptation Plan (see Section 2.1 for policy context), and water sector adaptation policy and strategy.

2. Policy context

In the UK, water suppliers are regulated by the Office of Water Services (Ofwat) who determine the price customers pay for water and monitor service provision, the Environment Agency, who have a duty to secure and ensure the proper use of water resources within the UK, and the Drinking Water Inspectorate who ensure that drinking water supplies are safe and of a high quality. Since the mid-2000s, there have been a series of mandates (e.g. Climate Change Act, Water Resource Management Plan, Environment Act) and high-profile reports such as the Pitt Review (2008), Letwin Review (2028) and Jenkins Review (2020) that have led to four areas of change in water management in response to our changing climate.

Initially, water suppliers needed to consider the impact of a changing climate on their water supply. Since 1999, water suppliers have been required to produce a Water Resource Management Plan (WRMP) every five years that details their 25-year plan for water supply and demand. This was implemented following the 1995/96 drought which saw northern water companies transferring water across the region using tankers (CEH, 2023). Since 2009, the impact of climate change on water resources must be factored in using Environment Agency guidance (Charlton and Arnell, 2011). Prior to this, water companies and academics were aware of the potential impact of climate change on water resources, and other associated issues such as low flow rates leading to higher concentrations of water pollution, but these were not quantified into water resource assessments. (Arnell and Delaney, 2006). In 2018 the report "Preparing for a drier future" (NIC, 2018) highlighted that risks from climate change to future water supplies were a key driver of the need to further reduce demand and leakage, but also plan at a more strategic level than through individual, company-level WRMPs. This subsequently led to the introduction of the Water Resources National Framework (Environment Agency, 2020). Water suppliers must also submit a Drought Plan every five years, and after each drought.

Secondly, the 2008 Climate Change Act introduced the requirement for reporting authorities to describe the measures they are taking to adapt to the risk and opportunities associated with climate change, namely the Adaptation Reporting Power (ARP). Reporting authorities include those organisations with a public function who provide or regulate statutory services such as transport, energy, water, or the historic or natural environment. The ARP feeds into the Climate Change Risk Assessment (CCRA) which informs the National Adaptation Plan (NAP), and together, this series of iterative reports are intended to prepare the UK for climate change (Defra, 2022a). The first round of ARP reports took place between 2010 and 2012; 91 organisations, including water utilities were mandated to report. The second round of ARP was between 2013 and 2016; organisations were invited, but participation was voluntary, with 87 organisations reporting. For organisations, studies of the first and second round of ARP reporting show the ARP to have raised awareness of both of climate risks, vulnerabilities, opportunities, and of the process of adaptation, to the corporate level and with stakeholders (Jude et al., 2017; Street and Jude, 2019). For policymakers, the ARP provided a 'bottom up' list of adaptation options (Street and Jude, 2019); for an inventory of adaptation actions see Jenkins et al., 2022. The third ARP officially concluded in 2021; a broader set of organisations were invited to report on a voluntary basis, and 97 reports were received. The quality of ARP reports continues to improve, however, the ARP and CCRA cycles have become misaligned so less than 5% of ARP reports informed the third round (CCC, 2022), and the adaptation gap, i.e. the difference between what has been done and what needs to be done to be resilient to future climate change continues to increase (CCC, 2023).

Thirdly, the Flood Water and Management Act (FWMA) was introduced in 2010. This requires partnership working across a range of organisations to address the risk associated with serious flooding. The FWMA implements the recommendations of the 2010 Pitt Review of the 2007 floods (for a discussion see Benson and Langstaff, 2016) and is framed within the context of a changing climate that includes more frequent and intense extreme rainfall events. The FWMA aims to reduce the risk of serious flooding via several measures, including: clarifying which Risk Management Authorities (RMAs) are responsible for which sources of flooding, creating the role of Lead Local Flood Authority (normally the local authority), to be responsible for managing flood risk from surface water and smaller rivers (the Environment Agency manage flood risk from main rivers, water companies manage flood risk from their sewer network); creating a register of those assets that affect flood risk in their areas (i.e. watercourses, flood defences (formal and informal), culverts and related structures like screens, and third party assets like railway or highway embankments if these act as flood defences); protecting customers against unaffordable increases in surface water drainage charges; and, protecting water supplies to customers/consumers. The Environment Agency works in partnership with Lead Local Flood Authorities and other RMAs to produce flood risk management plans for different river basins, on a six-year cycle. The first cycle took place from 2015-2021; current plans cover the cycle from 2021-2027 (Environment Agency, 2022).

The 2010 FWMA also called for the automatic right for developers to connect to sewers to be removed, alongside greater implementation of Sustainable Urban Drainage Systems (SuDS; “Schedule 3”). In the 2007 floods up to two thirds of flood water came from direct run-off from impervious surfaces overwhelming the sewer system (Ellis and Lundy, 2016). Mandating the implementation of SuDS has been delayed, uptake of SuDS has been slow (Melville-Shreeve et al., 2018), and the legal frameworks considered complex and ineffective (Potter & Vilcan, 2020; Ellis & Lundy, 2016). This is problematic given the increasing future flood risk from surface water flooding (Russell and Sayers, 2022), and the potential of SUDs to address other issues such as water quality, biodiversity, and mitigate urban heat risk (Green, 2019) and align with other key policies such as Biodiversity Net Gain (BNG). In 2020, Ofwat published the Code for Adoption, that allows water companies to legally adopt certain kinds of SUDs (although the right to connect remained). In 2023, following recommendations from a Defra Review (Defra, 2023) and earlier reviews by the Public Accounts Committee, and the Jenkins Review (2020) it was announced that Schedule 3 will become mandatory in 2024. This means that SuDS will become mandatory on new developments in England, developments will no longer have the automatic right to connect to the sewer system, and developments will need to have surface water drainage management plans. This has consequences for climate impacts, especially flooding, and facilitates new options for climate adaption including Nature Based Solutions (e.g. Stevens et al., 2023).

Most recently, the 2021 Environment Act makes provision about targets, plans and policies for improving the natural environment including water quality. For water and sewage companies, improvements to water quality will reduce drinking water treatment costs but will also require significant investment to address the issue of storm overflows that introduce pollution into water courses (Defra, 2022b). It requires water and sewage companies to produce Drainage and Wastewater Management Plans, to be published in 2023 (Water UK, 2022). These should include a 25-year risk-based consideration of current drainage and waste-water issues within the context of a changing climate and future extreme weather events. It will also require the government to produce a statutory plan for reducing storm overflows and for water and sewage companies to report annually on storm overflows and monitor overflows and provide notification of the occurrence and cessation of storm overflows within one hour of this taking place. Alongside this, the England Peat Action

Plan outlines a long-term vision to restore peatland to ensure that carbon is locked up in peat and therefore mitigate greenhouse gas emissions, which is also beneficial for drinking water resource (Defra 2021).

3. Yorkshire Water response within changing policy contexts

3.1 2011-2014 Understanding climate risk and adaptation

From 2011 to 2014, Yorkshire Water were operating under the 2009-2014 Water Resource Management Plan (WRMP) as approved prior to the 2009 Price Review. During this period, Yorkshire Water were required to submit their first ARP report, prepare the 2014-2019 WRMP for the 2014 Price Review, and begin implementing measures outlined in the 2010 FWMA (Figure 2). Although academic and practitioner articles from 1990s onwards had considered how climate change may impact water supply and water quality (e.g. Fowler et al., 2007; Dessai & Hulme, 2007; Arnell & Delaney, 2006; Arnell, 1998), and climate change was noted (but not quantified) in the 2009-20014 WRMP (Charlton and Arnell, 2011), these commitments required Yorkshire Water to understand climate change risks and adaptation measures across their entire operations, for the first time (Yorkshire Water, 2011). During this time, there were two extreme cold snaps (2009/10 and 2010/11), floods in 2012, and a storm surge in 2013.

The resources to support the first round of ARP were sparse and included: Statutory Guidance to Reporting Authorities (Defra 2009); UK Climate Change Projections 2009 (UKCP09; Defra 2011); and, coastal and fluvial flood maps from the Environment Agency. There was no government prescribed methodology, however Defra organised and attended workshops with industry and individual organisations to support the reporting process (CERF, 2012). For Yorkshire Water, there were weaknesses in terms of the data available and its suitability for undertaking climate risk assessment. Specifically:

- The Environment Agency flood maps showed the extent of possible flood events with different return periods for flooding from rivers or the sea. However, the maps did not describe the speed at which flooding would occur, the depth of flood waters, or the risk from surface water flooding, or the risk of flooding from the sewer network. Moreover, the maps did not include changes to flooding associated with climate change.
- UKCP09 products comprised gridded (25km grid) projections of precipitation change for three difference emissions scenarios: low, medium, and high (Defra, 2011), and a stochastic weather generator (Jones et al., 2009) that created synthetic time series of hourly and daily weather data on a 5km grid for three different emissions scenarios and three 30-year future time slices. UKCP09 was ground-breaking, but Yorkshire Water found it difficult to utilise the projections and weather generator for their climate risk assessment. Although the weather generator produced satisfactory monthly statistics, it lacked interannual variability (Chun et al., 2012), could not replicate the Yorkshire drought of 1995/96 (Fowler and Kislby, 2002), and Yorkshire Water required better representation of extreme multiyear extreme droughts to assess risk to future water supply, and changes to sub daily rainfall to assess sewer flooding risk.
- There was also little information on how climate change could exacerbate existing risk of wildfire, subsidence, erosion, or how water quality as well as quantity will be affected.

Consequently, the water sector commissioned a series of research reports to support their climate risk assessment and adaptation needs moving forward. For Yorkshire Water, these included a position paper (Yorkshire Water, 2012), three water resources related reports (Mott MacDonald, 2012; WrC 2012; WrC, 2013), and a series of investigations into the best way to apply climate change uplifts to sewer models (HR Wallingford, 2013). Moreover, in 2011, the Environment Agency published *Adapting to Climate Change* (Environment Agency 2011) that included uplifts for peak river flows and sea level rise, and the Cabinet Office produced *Keeping the Country Running* (Cabinet Office, 2011). The latter document gave, for the first time, some expectations as to the types of scenarios to which infrastructure providers were expected to be resilient, including: coastal flooding, inland flooding, storms and gales, low temperatures and heavy snow, heat waves, drought, volcanic ash and space weather (Cabinet Office, 2011). The document also introduced the four-box model for infrastructure resilience (Figure 3), which was widely adopted across the water sector and beyond and was further refined by the National Infrastructure Commission in their report Resilience – Anticipate, React, Recover (NIC, 2020).

The 2014-2019 WRMP provided an opportunity for Yorkshire Water to incorporate climate risk into their management planning. The UKCP09 data was released too late to be utilised for the 2014 Price Review (that approves the 2014-2019 WRMP), but new uplifts for peak river flows and sea level rise from the Environment Agency informed internal Design Guidance and Engineering Specification documents and enabled climate change to be incorporated in flood risk assessment and solution design. In the 2019 Price Review, Ofwat approved flood resilience for clean water supply sites, but did not approve the wastewater flood resilience programme because it only received 67% customer support (the bar being 70%), and Ofwat believed that the benefits from wastewater flood resilience were insufficiently quantified, in part because UKCP09 data was not used.

Lastly, in line with the FWMA that advocated partnership working, Yorkshire Water issued a performance commitment to work in partnership with others (e.g. Leeds City Council) to address surface water flooding risk. This was a new method of delivering solutions to shared risks and represented a significant shift in risk management.

3.2 2014-2019 Progressing climate risk and adaptation

During the 2014-2019 period, Yorkshire Water increasingly progressed their understanding of climate risk and began embedding adaptation into their policy and operations. Data and guidance to adapt to climate change had increased, and Yorkshire Water utilised water-sector focused research (e.g. Mott MacDonald, 2012; WrC 2012; WrC, 2013), which included the translation of UKCP09 into datasets suitable for use in water resources and sewer modelling (HR Wallingford, 2010; 2013) to undertake a comprehensive and wide ranging programme of climate risk assessment. This included implementing a programme of flood resilience outlined in their Business Plan, submitting the second ARP report under the Climate Change Act, and increasing partnership working regionally, to reduce flood risk (e.g. Flood Risk Management Plan 2015-2021) and nationally, to improve climate services produced by UKCP18. They also produced the WRMP 2019-2024 for approval in the 2019 Price Review.

Specifically, following the 2014 Price Review, Yorkshire Water's Flood Risk Guidance for new assets (designed to be resilient for 1 in 200 events) was established, along with a Flood Steering Group to assess and champion surface water flood risk partnerships, including a detailed flood risk assessment for the 150 most critical assets (Yorkshire Water, 2015). This led to adaptation measures at critical water supply sites such as higher flood walls, flood proofing walls, and raising vulnerable equipment.

Yorkshire Water submitted their second ARP report in 2015 (Yorkshire Water, 2015). During the second round of ARP, there was more evidence and support to adapt to climate change, including:

- More guidance for practitioners, and co-development of this guidance between Defra, Climate Change Committee and reporting companies, alongside several workshops within and across the sector about shared risks, what and how to report (Street & Jude, 2019).
- More support for embedding adaptation within the water sector, including updates to the UK Water Institute Research framework for climate adaptation (UK WIR, 2013).
- More evidence of the impacts of climate change from water sector research and the first Climate Change Risk Assessment (Defra, 2012).

- More water sector focused data to project changes to water supply and wastewater drainage (HR Wallingford, 2011; 2013).

The ARP outlined Yorkshire Water's priority climate risks, including ensuring water supply during changing rainfall patterns and future droughts, and managing surface water flood risk, sewer flooding, and coastal erosion, and the risk to water quality from degraded peatbog habitats (Yorkshire Water, 2015). 40% of raw water in the Yorkshire Water region is sourced from peatbog habitats and these habitats need to be in good condition to provide good quality water (Armstrong et al., 2010). Water from degraded peat habitats is high in dissolved organic carbon (DOC) and can be discoloured. This is expensive to remove and above a certain threshold (ca. 200 hazen) the water becomes untreatable with standard water treatment processes (Ritson et al., 2014). At that time, these risks were not recognised nationally (e.g. Defra, 2012; 2017). The ARP report also raised awareness of interdependencies as a source of unknown risk, of the policy barriers related to surface water management, particularly around the implementation of SuDS (e.g. design standards, ownership, maintenance, planning policy), and highlighted that Environment Agency flood maps do not include the impacts of climate change (Yorkshire Water 2015).

Regionally, Yorkshire Water were working in partnership with the Environment Agency and other flood risk authorities to manage: (i) surface water flood risk, including the first cycle of the Flood Risk Management Plan 2015-2021; and (ii) coastal flood risk, using the new National Coastal Erosion Risk Mapping (NCERM) to support risk assessments. This included working with Yorkshire Peat Partnership (2023) and Moors for the Future (2023), to align agendas and undertake research that improve peatland habitat, and therefore water quality. In 2016, the Beyond Nature initiative was launched to work with farmers to create mutually beneficial land management practices that support water resource management and Natural Flood Management (NFM; Yorkshire Water, 2023a). Nationally, Yorkshire Water and other water and sewage companies began sharing best practice in climate risk assessment and adaptation across the water sector, and all sectors, via the Infrastructure Operators Adaptation Forum, which brings together infrastructure organisations, local and national governments, Climate Change Committee, and others in practice and academia to share and guide best practice in infrastructure resilience to climate change. Yorkshire Water also support the development of climate services provided via UKCP18 (Norman et al., 2018)

At the end of this period, Ofwat undertook the 2019 Price Review for the 2014-2019 WRMP, which included information from UKCP09, and Yorkshire Water were permitted to include resilience measures for sewers. The rates of water bills were held flat for the customer, and four WaSCs took Ofwat to the Competition and Markets Authority for a redetermination following its 2019 price review (GOV UK 2021).

Lastly, there were extreme floods in 2015/16 (Marsh et al., 2016), that led to the Letwin Review (Cabinet Office, 2016). Following this, Yorkshire Water built back better by including an uplift for climate change when repairing flood damaged assets. There was further flooding in November 2019/2020 (Davies et al., 2021; Sefton et al., 2021), and drought in 2018 (Turner et al., 2021), that almost required a regional hosepipe ban.

3.3 2019-2023 Improving policy context and solutions for climate risk and adaptation

During the period between 2019-2023, Yorkshire Water were implementing climate change adaptation and climate risk management across a range of initiatives introduced in Section 3.1 and 3.2 (Figure 2). These included (i) implementing WRMP 19-24, which included data from UKCP09, and using UKCP18 to prepare for WRMP 2024-2029 and Price Review 24; (ii) implementation of FWMP 2015-21, which included data from UKCP09, before moving to FWMP 2021-27 (Environment Agency, 2022), which was underpinned by UKCP18; and (iii) submitting the third ARP report that used UKCP18 data (Yorkshire Water, 2021a). The period also includes the 2021 Environment Act and the introduction of: Natural Flood Management scheme in Calderdale (CFP, 2021), the National Framework for Water Resources (Environment Agency, 2020), the first Drainage and

Wastewater Management Plans (DWMP; Water UK, 2022), and the England Peat Action Plan (Defra, 2021). There is also the commitment to implementing Schedule 3 of the 2010 FWMA. (Section 2).

These new schemes, frameworks, and plans required systems thinking, landscape scale solutions, and long-term planning for climate risks, with delivery through partnership working. For example, *Living with Water* was launched, to manage flood risk in Hull and its surroundings, thereby formalising arrangements that had been in place since the 2007 floods (Coulthard & Frostick, 2010). *Living with Water* is a strategic partnership between Hull, East Riding Councils, University of Hull, Yorkshire Water, and the Environment Agency. Additionally, the National Framework for Water resources requires partnership working to create regional plans across neighbouring water companies to provide a 1 in 500 level of resilience to drought (Environment Agency, 2020). These plans use datasets developed from UKCP18 to assess future water supply (Atkins, 2021), and also include projections of future water demand (e.g. from changing industrial needs, irrigation, power supply, hydrogen); drafts for consultation were produced in 2022 (WReN, 2022). To further increase resilience of water supply, in 2019 Ofwat, the Environment Agency and the Drinking Water Inspectorate created RAPID (Regulators' Alliance for Progressing Infrastructure Development). RAPID supports the implementation of the National Framework for Water Resources by promoting Strategic Resource Options (SRO) for future water resources (new reservoirs, transfers and reuse schemes) that involve more than one water company, through a gated process to ensure that projects are developed quickly, to a high standard, and through efficient spend of customers' money.

The 2022 DWMP (Yorkshire Water, 2023b) considers current and future risk of flooding from the sewer network and places wastewater drainage on the same long term planning basis as water resources, thereby ensuring that both clean and waste sides of the business have 25 year forward plans which include the impact of climate change, population growth and changes to industry. The DWMPs are focused on the hydraulic capacity of the sewer network and how it will be affected by climate change, population growth and urban creep (the ongoing loss of permeable areas due to front gardens being paved over, infill development etc). Yorkshire Water's DWMP shows an increasing risk of sewer flooding and highlights the significant cost of reducing the risk (£1.47bn by 2030, £36bn by 2050[1]). The DWMP also include Environment Act targets to reduce storm overflows to 10 spills or less per year.

This period also included extreme weather events and the covid 19 pandemic. The latter disrupted historical patterns of water usage shifting water demand from non-household consumption (e.g. city centre working, hospitality venues) to household customers, and changing revenue sources (Renukappa et al., 2021). Extreme weather included extreme cold and storms 2021/22 (Met Office, 2022), which led to power loss with implications for water pumping in rural areas. This was followed by a drought and the hottest UK day on record in July 2022 when temperatures exceeded 40°C (Met Office 2022); there were hosepipe bans in parts of England including, for the first time since the mid-1990s, the Yorkshire Water region.

4. Discussion

Over the last 10 years, Yorkshire Water have significantly increased their understanding of the impacts of weather and climate change on their infrastructure and operations, and increasingly embedded climate change adaptation within their business as usual (Section 3). This has been driven by changing policy frameworks, changing business needs, and changing societal demands – which in turn drive business needs for public utilities, and often influence government and Ofwat policy and actions. For example, the damage and disruption caused by the 2007 floods led to the Pitt Review, the recommendations of which led to the FWMA 2010. There has been a shift from managing water in isolation, predominantly via hard engineering,

[1] https://www.yorkshirewater.com/media/5l1jkll2/yw_dwmp24_customer_report_final.pdf

to managing water as part of the landscape as part of natural processes, through partnership working. These changing societal contexts and approaches to land and water management are discussed below.

Water is the core product of the water sector, and accordingly the sector is intrinsically aware of weather and climate. Climate change impacts to water supply were considered before the introduction of the climate change act. However, the advent of the ARP process in 2011 required Yorkshire Water and water companies to create or extend roles to include climate risk for the first time. Extreme weather events such as the 2007 floods highlighted the need for effective surface water management, and the increasing risk of similar events given that UKCP09 projections indicated an increase in the frequency and intensity of heavy rainfall events (Jones et al., 2009). However, public opinions on climate change at this time were split (Taylor et al., 2014; Clements, 2012). Whilst most of the public had heard of climate change, there was public uncertainty and scepticism regarding its cause and the scale of likely impacts, and it remained of low importance to many people (Pigeon, 2012). Yorkshire Water published a position statement (Yorkshire Water, 2012), signed by the Board, listing the evidence for anthropogenic climate change, the impact of recent extreme weather events, and acknowledging that action was required to protect the long-term provision of essential services. This clarity enabled progress within the company and avoided individuals having to argue with colleagues over the science. As such, Yorkshire Water, and others in the sector were early leaders in infrastructure adaptation, submitting their adaptation plans first (Jude et al., 2017), commissioning the reports required to support their adaptation plans, undertaking adaptation following the 2014 Price Review, building back better following the 2015/16 floods, adopting an adaptation pathways approach before other infrastructure operators in the 2019 WRMPs and recording the highest number of adaptations actions in the UK adaptation inventory (Jenkins, et al. 2022).

Public concern regarding the impact of climate change has increased in the last 10 years (BEIS, 2020). High profile people and/or associated activities such as Sir David Attenborough, Greta Thunberg, 2018 School Strikes for Climate, and disruptive activities by Extinction Rebellion have brought climate change narratives into mainstream news and conversations (Bevan et al., 2020). However, customer-focused market research (Yorkshire Water, 2016) by Yorkshire Water shows that many water customers were (and still are) largely unaware of the range of things their water company does. Water and sanitation are reliable and “hidden” services – few people are aware of where their water comes from, how it is treated, or how sewage is collected, treated, or discharged. When prompted in customer research forums about environmental issues and water, some customers may make a connection with saving water but few are aware of the potential impact of climate change on water availability or of other climate risks such as flooding or wildfires and how these may impact on them or the ability of their water company to continue providing services during their lifetimes. Few customers are aware of the impact of climate change on the risk of sewer flooding or storm overflows, or how customer actions such as putting prohibited items into sewers (e.g. wet wipes, Fats, Oils, and Grease FOGs) can exacerbate the problem.

The last 10 years have also brought about significant changes in the approach to water management. Historically, water and sewage companies worked in isolation to: (i) ensure sufficient clean water supply through water resource management and water treatment, and (ii) remove unwanted water away via hard engineering solutions (Figure 4). There is now greater consideration of the role of the landscape in ensuring sufficient and high-quality clean water, or in terms of reducing flood risk as exemplified by increasing partnership working, and new legislation such as the Environment Act and the England Peat Action Plan (Figure 2). The second ARP report (Yorkshire Water, 2015) and the underpinning academic and practitioner reports (see Section 3.2) increased the organisational understanding of the importance of managing peat bogs for water supply. Landscape is also central to the 2015 Calderdale NFM project, and the need to deliver these landscape-level solutions fed into a shift from silo-working to partnership-working that was taking place within Yorkshire Water (such as Living with Water, see Section 3.3) and across the sector more broadly, in line with the 2010 FWMA. More recently, regional partnerships are increasing the resilience of future water supply via the National Framework for Water Resources and RAPID.

In addition to disrupting historical water demand (Renukappa et al., 2021), the Covid 19 pandemic also changed the relationship that people have with the natural environment with consequences for water and sewage companies. There was an increased public awareness of both the natural environment and its positive associations with human heath (Labib et al., 2022), and nature-related topics, including sources of environmental pollution (Rousseau and Deschacht, 2020). There was also an increase in river swimming (Roviello et al., 2022). Consequently, there is now raised awareness of pollution from sewage overflows, contributing to the Ofwat investigation of wastewater compliance started in 2022, the implementation of Schedule 3 in 2024, and, the mandatory reduction of overspills enshrined in the 2021 Environment Act.

Lastly, these shifts in water management in response to a changing climate come with changed expectations for the customer. There is increased public understanding of climate change and the importance of effective water management (Yorkshire Water, 2021a), but these have not been accompanied by increases in the amount that customers pay for water, creating a challenging environment for water utilities (Yorkshire Water, 2016).

5. Conclusions

This longitudinal examination of climate change adaptation demonstrates that there has been a shift in the understanding of climate change, climate risk, and the importance of the natural environment within Yorkshire Water. This has been driven by an increase in the number of extreme events, public and organisational experiences of living through and/or managing extreme events, high profile public reports into the impact of extreme events, changed reporting requirements for climate change, the increased availability of climate data and climate services specifically to support the water sector, and the covid pandemic (Figure 2). Moving forward, the implementation of Schedule 3 in 2024 alongside the new policies and partnership working for flood risk, wastewater management, and water resources, and future iterations of ARP and CCRA will enable and support ongoing climate adaptation at Yorkshire Water.

Climate adaptation is an iterative process (Quinn et al., 2018) and challenges remain. Moving forward, how should the water sector manage interdependencies with other sectors, such as energy and information communications technology (ICT)? How should adaptation actions be prioritised? There are solutions for most climate risks, but insufficient funding for all adaptation measures required. For example, should every water pump have a backup generator in case of power loss, and if so, should the customer pay for this? Moreover, the water sector has multiple regulatory frameworks, the planning timescales for which don't align (Figure 2). Indeed, even within specific frameworks there is misalignment; the ARP reports should feed into the Climate Change Risk Assessments. In both 2015 and 2021, the ARP reporting process was completed after the publication of the respective CCRA. Furthermore, the multiple regulatory frameworks and partnerships required can also make accessing funding difficult. For example, the government flood defence grant-in-aid (FDGIA) calculator allows for organisations to claim flood risk reduction benefits for a single source of flooding. However, in the case of Hull, which has existing sea defences it has proved problematic to access FDGIA funding to resolve surface water flood risk as those properties have already benefited from public funding to protect from coastal flooding.. NFM and SUDS provide multiple benefits for people, nature, and built environment and infrastructure resilience, but are also complex to deliver due to different regulatory regimes, and funding cycles for utility providers and local authorities. At same time there is declining public willingness to increase payments for their water supply and processing, particularly during the cost-of-living crisis, and as well as declining tolerance of infrastructure failure, and increasing risk from our changing climate. A public awareness campaign (and dialogue) about climate risk and the role of the water sector, and the actions that individual can take, may help raise awareness of the important and varied role of water and sewage companies have in adapting to climate change.

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References

Armstrong, A., Holden, J., Kay, P., Francis, B., Foulger, M., Gledhill, S., McDonald, A.T. and Walker, A., 2010. The impact of peatland drain-blocking on dissolved organic carbon loss and discolouration of water; results from a national survey. Journal of Hydrology, 381(1-2), pp.112-120. https://doi.org/10.1016/j.jhydrol.2009.11.031

Arnell, N.W., 1998. Climate change and water resources in Britain. Climatic Change, 39(1), pp.83-110. https://doi.org/10.1023/A:1005339412565

Arnell, N.W. and Delaney, E.K., 2006. Adapting to climate change: public water supply in England and Wales. Climatic Change, 78(2-4), pp.227-255. https://doi.org/10.1007/s10584-006-9067-9

Atkins, 2021, Regional Water Resources Planning: Climate Data Tools Draft Operational Framework for implementing the EA Supplementary Guidance on Climate Change

Bevan, L.D., 2020. Climate change strategic narratives in the United Kingdom: emergency, extinction, effectiveness. *Energy research & social science*, *69*, p.101580. https://doi.org/10.1016/j.erss.2020.101580

BEIS 2020 Public Attitudes Tracker (March 2020, Wave 33, UK). Department for Business, Energy, and Industrial Strategy.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/884028/BEIS_PAT_W33_-_Key_findings_Final_.pdf Accessed 05/06/23.

Benson, D., Fritsch, O. and Langstaff, L., 2018. Local flood risk management strategies in England: Patterns of application. *Journal of Flood Risk Management*, *11*, pp.S827-S837. https://doi.org/10.1111/jfr3.12264

Cabinet Office, 2011. Keeping the Country Running: Natural Hazards and Infrastructure. A Guide to improving the resilience of critical infrastructure and essential services. Cabinet Office. October, 2011.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/61342/natural-hazards-infrastructure.pdf Accessed 24/5/23.

Cabinet Office, 2016. National Flood Resilience Review. Policy Paper. Published
8 September 2016.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/551137/national-flood-resilience-review.pdf Accessed 2/6/2023.

CCC 2022. Understanding climate risks to UK infrastructure-Evaluation of the third round of the Adaptation. Climate Change Committee. July 2022. Accessed 22/5/23. https://www.theccc.org.uk/publication/understanding-clima.te-risks-to-uk-infrastructure-evaluation-of-the-third-round-of-the-adaptation-reporting-power/

CCC 2023. Progress in adapting to climate change – 2023 Report to Parliament. Climate Change Committee. March 2023. Accessed 22/5/23 https://www.theccc.org.uk/publication/progress-in-adapting-to-climate-change-2023-report-to-parliament/#downloads

CEH 2023 the Tanker Drought – 1995-1998. Drought Inventory. https://www.ceh.ac.uk/our-science/projects/tanker-drought-1995-1998 Accessed 05/06/2023.

CERF, 2012. Evaluating the Risk Assessment of Adaptation Reports Under the Adaptation Reporting Power – Final Summary. Report for Defra's Adapting to Climate Change Programme. Centre for Environmental Risks and Futures, Cranfield University, 2012. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/183427/annex-b-cranfield-uni-report-arp.pdf Accessed 2012.

CFP 2021 5 Years of the Caldervale Flood Action Plan (2016-2021). Caldervale Flood Programme. https://eyeoncalderdale.s3.amazonaws.com/wp-content/uploads/2022/03/15110328/5-Years-of-the-Calderdale-Flood-Action-Plan-infographic.jpg Accessed 02/06/23.

Charlton, M.B. and Arnell, N.W., 2011. Adapting to climate change impacts on water resources in England—an assessment of draft water resources management plans. *Global Environmental Change*, *21*(1), pp.238-248. https://doi.org/10.1016/j.gloenvcha.2010.07.012

Chun, K.P., Wheater, H.S. and Onof, C., 2013. Comparison of drought projections using two UK weather generators. Hydrological sciences journal, 58(2), pp.295-309. https://doi.org/10.1080/02626667.2012.754544

Clements, B., 2012. Exploring public opinion on the issue of climate change in Britain. British Politics, 7, pp.183-202. https://doi.org/10.1057/bp.2012.1

Coulthard, T.J. and Frostick, L.E., 2010. The Hull floods of 2007: implications for the governance and management of urban drainage systems. Journal of Flood Risk Management, 3(3), pp.223-231. https://doi.org/10.1111/j.1753-318X.2010.01072.x

Davies, P.A., McCarthy, M., Christidis, N., Dunstone, N., Fereday, D., Kendon, M., Knight, J.R., Scaife, A.A. and Sexton, D., 2021. The wet and stormy UK winter of 2019/2020. Weather, 76(12), pp.396-402. https://doi.org/10.1002/wea.3955

Defra 2009 Adapting to Climate Change: helping key sectors to adapt to climate change Statutory Guidance to Reporting Authorities 2009. Defra 2009. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/182610/Adapting-to-Climate-Change-helping-key-sectors-to-adapt-to-climate-change.pdf Accessed 24/5/23.

Defra 2011 Adapting to climate change: UK climate projections 2009. Policy Paper. Defra. 28th March 2011. https://www.gov.uk/government/publications/adapting-to-climate-change-uk-climate-projections-2009 Accessed 24/5/23.

Defra, 2012. UK climate change risk assessment: Government report 2012. Policy Paper. https://www.gov.uk/government/publications/uk-climate-change-risk-assessment-government-report Accessed 02/06/2023.

Defra, 2017. UK climate change risk assessment: Government report 2017. Policy Paper. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/584281/uk-climate-change-risk-assess-2017.pdf
Accessed 02/06/2023.

Defra, 2020. Surface water and drainage: review of responsibilities. Department for Environment, Food & Rural Affairs. Published 26 August 2020. Last updated 30 July 2021. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911812/surface-water-drainage-review.pdf Accessed 05/06/2023.

Defra, 2021 England Peat Action Plan. Policy Paper. Department for Environment, Food & Rural Affairs. Published 18th May, 2021. https://www.gov.uk/government/publications/england-peat-action-plan Accessed 24/5/23.

Defra 2022a Climate change adaptation: policy information. Policy Paper. Department for Environment Food & Rural Affairs. Updated 11th August 2022. Accessed 21/5/23. https://www.gov.uk/government/publications/climate-change-adaptation-policy-information/climate-change-adaptation-policy-information

Defra 2022b September 2021: Water factsheet (part 5) Policy Paper. 1st April 2022. https://www.gov.uk/government/publications/environment-bill-2020/10-march-2020-water-factsheet-part-5 Accessed 24/5/23

Defra, 2023 The review for implementation of Schedule 3 to The Flood and Water Management Act 2010. January 2023. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1128073/The_review_for_implementation_of_Schedule_3_to_The_Flood_and_Water_Management_Act_2010.pdf Accessed 05/06/23.

Dessai, S. and Hulme, M., 2007. Assessing the robustness of adaptation decisions to climate change uncertainties: A case study on water resources management in the East of England. Global environmental change, 17(1), pp.59-72. https://doi.org/10.1016/j.gloenvcha.2006.11.005

Ellis, J.B. and Lundy, L., 2016. Implementing sustainable drainage systems for urban surface water management within the regulatory framework in England and Wales. Journal of Environmental Management, 183, pp.630-636. https://doi.org/10.1016/j.jenvman.2016.09.022

Environment Agency (2011) Adapting to climate change: guidance for risk management authorities. Environment Agency. Published 1st September 2011. https://www.gov.uk/government/publications/adapting-to-climate-change-for-risk-management-authorities Accessed 24/5/23.

Environment Agency 2020 Meeting our Future Water Needs: a National Framework for Water Resources. Environment Agency. Published 2020. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/873100/National_Framework_for_water_resources_summary.pdf Accessed 02/2/23.

Environment Agency (2022) Flood risk management plans 2021 to 2027. Environment Agency. Published 12 December 2022. https://www.gov.uk/government/collections/flood-risk-management-plans-2021-to-2027 Accessed 24/5/23.

Fowler, H.J. and Kilsby, C.G., 2002. A weather-type approach to analysing water resource drought in the Yorkshire region from 1881 to 1998. *Journal of Hydrology*, *262*(1-4), pp.177-192. https://doi.org/10.1016/S0022-1694(02)00034-3

Fowler, H. J., Kilsby, C. G., and Stunell, J.: Modelling the impacts of projected future climate change on water resources in north-west England, Hydrol. Earth Syst. Sci., 11, 1115–1126, https://doi.org/10.5194/hess-11-1115-2007

GOV UK 2021. Ofwat Price Determinations. Competition and Markets Authority. Published 19 March 2020. Last updated 9 April 2021. https://www.gov.uk/cma-cases/ofwat-price-determinations Accessed 02/06/2023.

Green, A., 2019. Sustainable drainage systems (SuDS) in the UK. Urban Stormwater and flood management: Enhancing the Liveability of cities, pp.69-101.

HR Wallingford, 2011. Using UKCP09 in water resources planning.

HR Wallingford, 2013. Using UKCP09 in sewer network modelling.

Jenkins, K., Ford, A., Robson, C. and Nicholls, R.J., 2022. Identifying adaptation ‘on the ground’: Development of a UK adaptation Inventory. *Climate Risk Management*, p.100430. https://doi.org/10.1016/j.crm.2022.100430

Jones PD, Kilsby CG, Harpham C, Glenis V, Burton A. UK Climate Projections science report: Projections of future daily climate for the UK from the Weather Generator. University of Newcastle, UK (2009). https://eprints.ncl.ac.uk/175886 Accessed 24/5/2023.

Jude, S.R., Drew, G.H., Pollard, S.J., Rocks, S.A., Jenkinson, K. and Lamb, R., 2017. Delivering organisational adaptation through legislative mechanisms: evidence from the Adaptation Reporting Power (Climate Change Act 2008). *Science of the Total Environment*, *574*, pp.858-871. https://doi.org/10.1016/j.scitotenv.2016.09.104

Labib, S.M., Browning, M.H., Rigolon, A., Helbich, M. and James, P., 2022. Nature's contributions in coping with a pandemic in the 21st century: A narrative review of evidence during COVID-19. Science of The Total Environment, p.155095. https://doi.org/10.1016/j.scitotenv.2022.155095

Marsh, T., Kirby, C., Muchan, K., Barker, L., Henderson, E. and Hannaford, J., 2016. The winter floods of 2015/2016 in the UK-a review. NERC/Centre for Ecology & Hydrology. https://nora.nerc.ac.uk/id/eprint/515303/

Melville-Shreeve, P., Cotterill, S., Grant, L., Arahuetes, A., Stovin, V., Farmani, R. and Butler, D., 2018. State of SuDS delivery in the United Kingdom. Water and Environment Journal, 32(1), pp.9-16. https://doi.org/10.1111/wej.12283

Met Office, 2022 Record breaking temperatures for the UK. Press Office. https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2022/red-extreme-heat-warning-ud Accessed 05/06/2023.

Moors for the Future (2023) Moors for the Future Partnership. https://www.moorsforthefuture.org.uk/ Accessed 02/06/2023.

Mott MacDonald, 2012. Climate change trends and evidence analysis for Yorkshire Water.

Norman, J. Rabb, B. Dessai, S. 2018. Assessing climate change risk in Yorkshire. Piloting new climate change projections with regional stakeholders in Yorkshire catchments. icasp - University of Leeds. https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-demo-projects/2-leeds.pdf Accessed 02/06/2023.

NIC 2018 Preparing for a drier future. Resilient Infrastructure Systems. National Infrastructure Commission https://nic.org.uk/nic-preparing-for-a-drier-future-26-april-2018/ Accessed 24/4/23.

NIC 2020 Anticipate, React, Recover. Resilient Infrastructure Systems. National Infrastructure Commission. May 2020. https://nic.org.uk/app/uploads/Anticipate-React-Recover-28-May-2020.pdf Accessed 24/4/23.

Potter, K. and Vilcan, T., 2020. Managing urban flood resilience through the English planning system: Insights from the ‘SuDS-face’. Philosophical Transactions of the Royal Society A, 378(2168), p.20190206. https://doi.org/10.1098/rsta.2019.0206

Pidgeon, N., 2012. Public understanding of, and attitudes to, climate change: UK and international perspectives and policy. *Climate Policy*, *12*(sup01), pp.S85-S106. https://doi.org/10.1080/14693062.2012.702982

Pitt, M., 2008. Learning lessons from the 2007 floods. Cabinet Office. UK Government. June 2008. http://webarchive.nationalarchives.gov.uk/20100807034701/http:/archive.cabinetoffice.gov.uk/pittreview/thepittreview/final_report.html Accessed 24/5/23.

Quinn, A.D., Ferranti, E.J., Hodgkinson, S.P., Jack, A.C., Beckford, J. and Dora, J.M., 2018. Adaptation becoming business as usual: A framework for climate-change-ready transport infrastructure. Infrastructures, 3(2), p.10. https://doi.org/10.3390/infrastructures3020010

Renukappa, S., Kamunda, A. and Suresh, S., 2021. Impact of COVID-19 on water sector projects and practices. Utilities Policy, 70, p.101194. https://doi.org/10.1016/j.jup.2021.101194

Ritson, J.P., Graham, N.J.D., Templeton, M.R., Clark, J.M., Gough, R. and Freeman, C., 2014. The impact of climate change on the treatability of dissolved organic matter (DOM) in upland water supplies: A UK perspective. Science of the Total Environment, 473, pp.714-730. https://doi.org/10.1016/j.scitotenv.2013.12.095

Rousseau, S., Deschacht, N. Public Awareness of Nature and the Environment During the COVID-19 Crisis. Environ Resource Econ 76, 1149–1159 (2020). https://doi.org/10.1007/s10640-020-00445-w

Roviello, V., Gilhen-Baker, M., Roviello, G.N. et al. River therapy. Environ Chem Lett 20, 2729–2734 (2022). https://doi.org/10.1007/s10311-021-01373-x

Russell, A. and Sayers, P., 2022. Assessing Future Flood Risk and Developing Integrated Flood Risk Management Strategies: A Case Study from the UK Climate Change Risk Assessment. Sustainability, 14(21), p.13945. https://doi.org/10.3390/su142113945

Sefton, C., Muchan, K., Parry, S., Matthews, B., Barker, L.J., Turner, S. and Hannaford, J., 2021. The 2019/2020 floods in the UK: a hydrological appraisal. Weather, 76(12), pp.378-384. https://doi.org/10.1002/wea.3993

Stevens, P.J., Stevens, A.J., Ferranti, E.J.S., Sharifi, S. and James, S. First Steps in Urban Water. 2023. A Trees and Design Action Group (TDAG) Guidance Document. UK: London. Available from: http://epapers.bham.ac.uk/4284/ Trees and Design Action Group http://www.tdag.org.uk/

Street, R.B. and Jude, S., 2019. Enhancing the value of adaptation reporting as a driver for action: lessons from the UK. *Climate Policy*, *19*(10), pp.1340-1350. https://doi.org/10.1080/14693062.2019.1652141

Taylor, A.L., Dessai, S. and de Bruin, W.B., 2014. Public perception of climate risk and adaptation in the UK: A review of the literature. Climate Risk Management, 4, pp.1-16. https://doi.org/10.1016/j.crm.2014.09.001

Turner, S., Barker, L.J., Hannaford, J., Muchan, K., Parry, S. and Sefton, C., 2021. The 2018/2019 drought in the UK: a hydrological appraisal. Weather, 76(8), pp.248-253. https://doi.org/10.1002/wea.4003

UK WIR, 2013. Updating the UK Water Industry Adaptation Framework. UKWIR Climate Change Adaptation Handbook. Report Ref. No. 12/CL/01/18. UK Water Industry Research. 2013. https://ukwir.org/reports/12-CL-01-18/66618/Updating-the-UK-Water-Industry-Climate-Change-Adaptation-Framework--UKWIR-Climate-Change-Adaptation-Framework-Handbook

Water UK, 2022. Drainage and Wastewater Management Plans https://www.water.org.uk/policy-topics/managing-sewage-and-drainage/drainage-and-wastewater-management-plans/ Accessed 24/5/23.
Wheeler, D., 2013. Regional weather and climates of the British Isles-Part 4: North East England and Yorkshire. *Weather*, *68*(7), pp.184-190. https://doi/pdf/10.1002/wea.2081

WrC, 2012. Duration modelling; impact of multi-year drought events on resources and assets.

WrC, 2013. Water use in homes built to Part G building regulations and Code for Sustainable Homes water efficiency design standards.

WReN 2022 Draft Regional Plan for consultation Appendix 1: Meeting the needs of the National Framework. Water Resources North. November 2022. https://www.waterresourcesnorth.org/globalassets/wrmp/wren/wren-drp-2022---appendix-1---meeting-the-needs-of-the-national-framework.pdf Acccessed 03/06/2023.

Yorkshire Peat Partnership, 2023. Yorkshire Peat Partnership https://www.yppartnership.org.uk/ Accessed 2/6/2023.

Yorkshire Water, 2011. Adapting to Climate Change. Maintaining Levels of Service in a Changing Climate. Yorkshire Water. January 2011. https://www.gov.uk/government/publications/adaptation-reporting-power-received-reports Accessed 24/5/23

Yorkshire Water, 2012. Climate change and weather resilience – a position paper.

Yorkshire Water, 2015. Adapting to a changing climate Yorkshire Water's Adaptation Report 2015. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/474358/climate-adrep-yorkshire-water.pdf Accessed 02/06/23.

Yorkshire Water, 2016. Yorkshire Water PR19 Valuing Water Topline qualitative report. December 2016. Not publicly available.

Yorkshire Water, 2021a. Adaptation Report 2020/2021. October 2021. https://www.yorkshirewater.com/media/gh5lxp3a/yw_adaptation_report_2021.pdf Accessed 02/06/23.

Yorkshire Water, 2021b. Your water. Climate Change Survey topline results. August 2021. Commercial market research. Not publicly available.

Yorkshire Water, 2023a. Beyond nature. https://www.yorkshirewater.com/environment/beyond-nature/ Accessed 02/02/3023.

Yorkshire Water 2023b. Drainage and wastewater management plan https://www.yorkshirewater.com/about-us/drainage-and-wastewater-management-plan/ Accessed 02/02/3023.

Figures

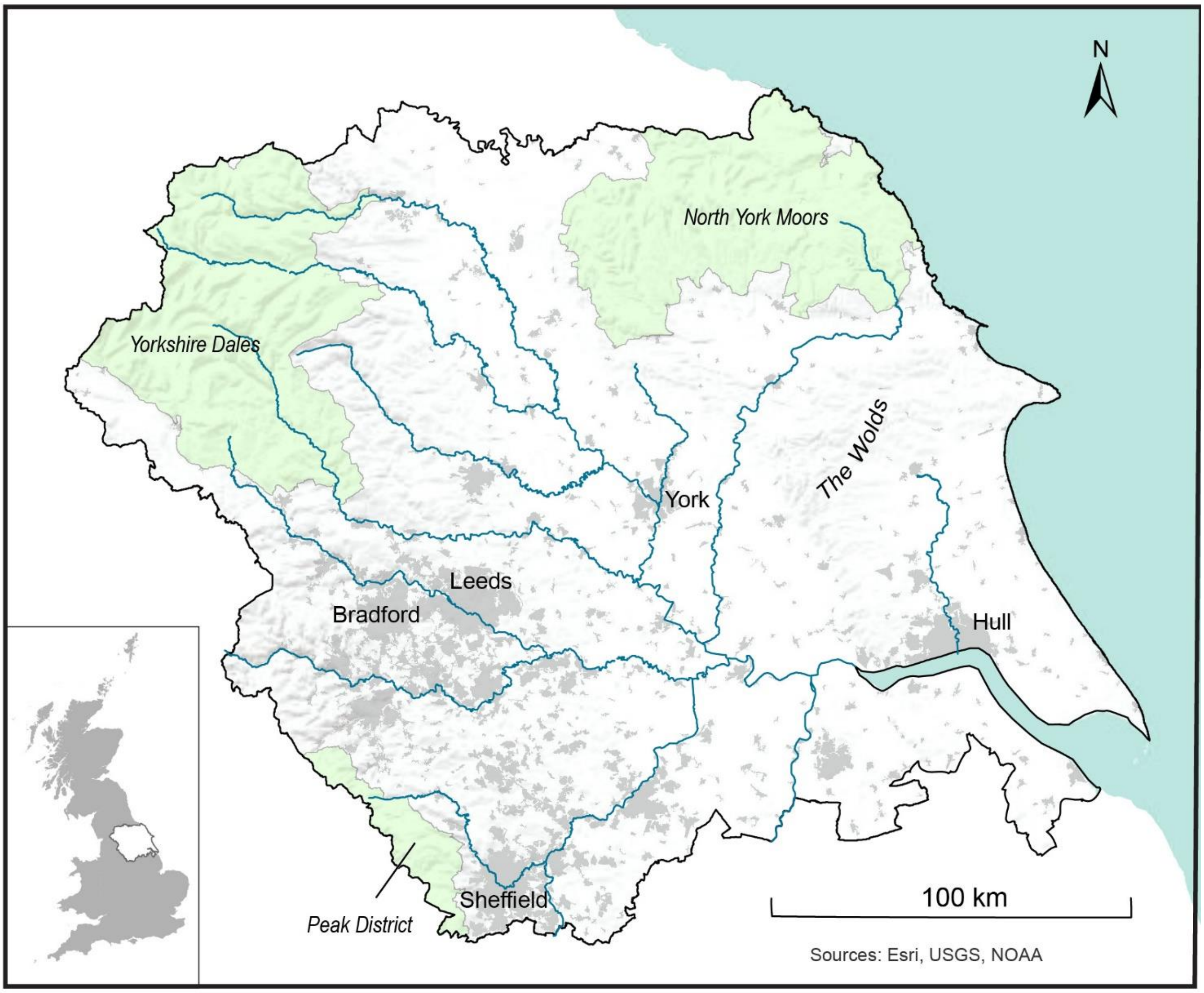

Figure 1: Map of Yorkshire and Humberside

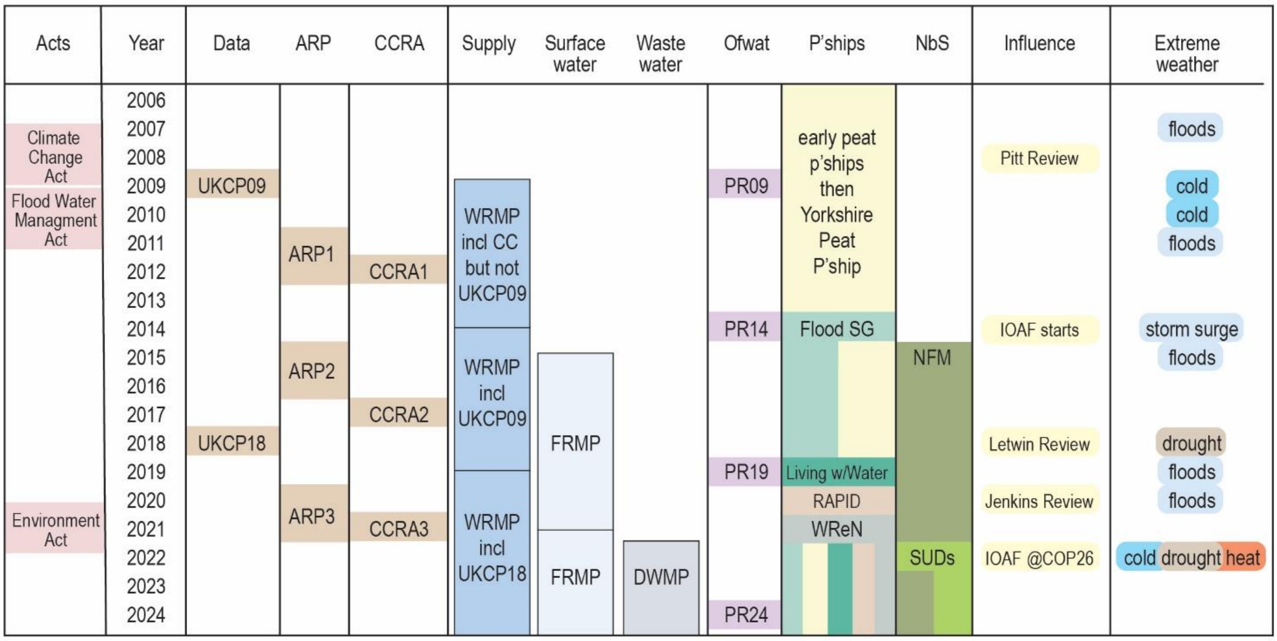

Figure 2 Timeline of different acts, policies, strategies, plans, partnerships, influencing factors such as reviews and extreme weather related to climate resilience at Yorkshire Water. Abbreviations and acronyms are as follows: UKCP-UK Climate Projections; ARP-Adaptation Reporting Power; CCRA – Climate Change Risk Assessment; CC – Climate Change; WRMP-Water Resource Management Plan; FRMP – Flood Risk Management Plan; DWMP – Drainage and Wastewater Management Plan; PR-Price Review; SG – Steering Group; RAPID - Regulators' Alliance for Progressing Infrastructure Development; WReN – Water Resources North; SUDs Sustainable Drainage Systems; NFM – Natural Flood Management; IOAF – Infrastructure Operators Adaptation Forum; NbS – Nature based Solutions.

Figure 3: The different components of infrastructure resilience. Image taken from a 2011 Cabinet Office report: Keeping the Country Running (Cabinet Office, 2011).

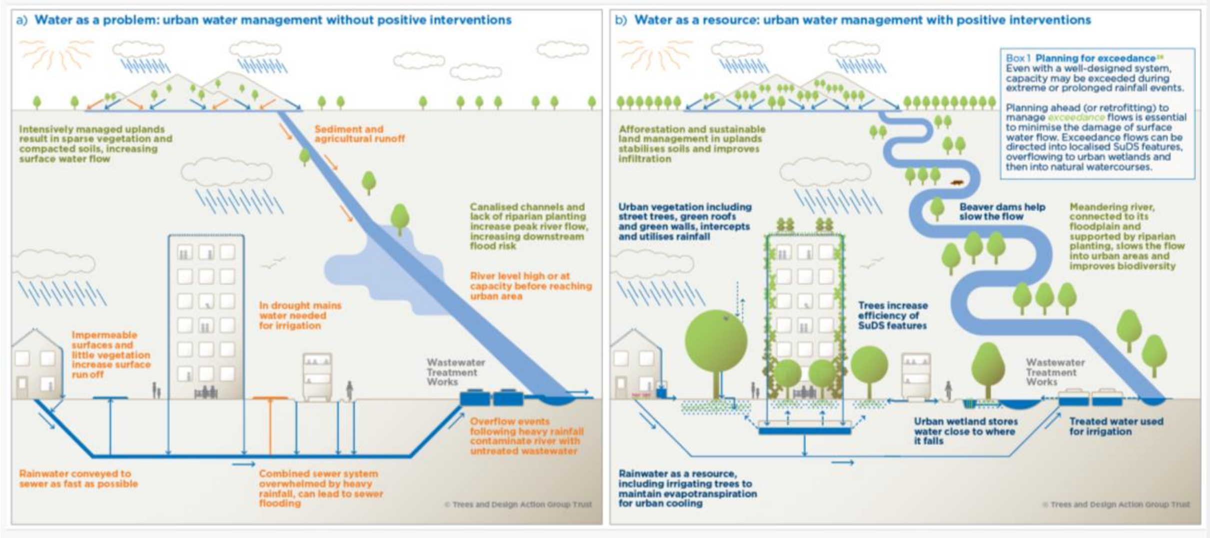

Figure 4. Diagram depicting the difference between (a) managing water as a problem, and (b) managing water as a resource. From Stevens et al., 2023. Copyright TDAG Trust